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Demonstration Test for Determining Spent Nuclear Fuel Inspection Method for Dry Storage

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1. Introduction

Spent Nuclear Fuel (SNF) is generally stored in spent fuel pool (SFP), dry casks and dry storage etc. At present, all PWR SNF of KHNP are stored in spent fuel pool at individual nuclear plant. However the domestic storage capacity is expected to be saturated after 2025, respectively.[1] The interim dry storage is considered as a solution to the saturation of SNF storage capacity of spent fuel pool.[2] For dry storage, defect inspection of SNF should be preceded by regulations. Currently, the methods of defect inspection in KHNP are visual testing (VT), Ultrasonic testing (UT) and in-mast sipping test (IMS). VT is mainly to inspect defects of fuel assembly structure, spacer grid and outermost fuel rod. UT can detect the defect fuel rod inner fuel assembly. IMS can find defect assembly, but not fuel rod. Demonstration test for UT was conducted as a part of determining SNF inspection method.

2. Demonstration Test and Results

2.1 Ultrasonic Test

Ultrasonic testing of SNF is performed in the underwater environment of SFP. As the UT probe progresses continuously between fuel rods, it determines the defect by the size of the detection signal entered in the receiver. It takes about 10 minutes per SNF and the measurement procedure is simple, but detection signal can be affected by presence of moisture in the gap between cladding and pellet, scales and CRUD of cladding surface, probe alignment, etc. Depending on whether moisture exists in the gap, the received signal may appear as shown in Fig.1.

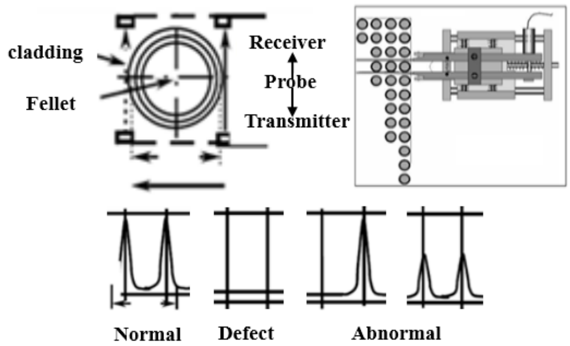

Fig. 1. Ultrasonic test Schematic and Signal Types

2.2 System and signal settings

Demonstration test equipment used the UT system currently used in plants. To determine fuel defect through detected signal, the transmitter and receiver initial setting of the signal was performed. Probe transmitter frequency used 10MHz and 5MHz. The detected signal that passes through the inside of the cladding to the detector is measured for 1microsecond from the time of initial signal detection. After reference test to the recently released twice-burned normal fuel, the gain was set at 80% level of the reference fuel, and the gate was set 1/2 level of the reference fuel.

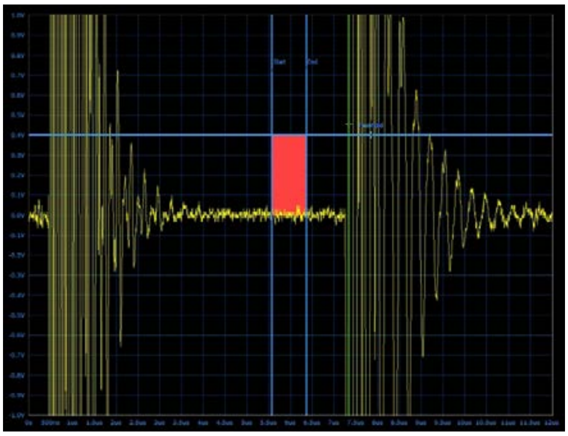

Fig. 2. Initial setting values of gain and gate after reference test to the recently released twice-burned normal fuel.

2.3 Selection for the Subjects

When selecting the subjects, several conditions were combined for fuel type, fuel burnup, cooling time, defect fuel. To verify the characteristics of detected ultrasonic signal, we divided them into long term cooling high burnup fuel, long term cooling low burnup fuel, short term cooling high burnup fuel and short term cooling low burnup fuel. And signal characteristics of defected fuel assemblies which were previously judged to be defective were also verified. As a result, the subjects for demonstration test were to select each 33ea and 32ea SNF for WH type and KSNP type. The distribution of fuel stored in WH plant SFP by cooling period and burnup is shown in Fig. 3. SNF classification for WH type and KSNP type is shown in Table I and II

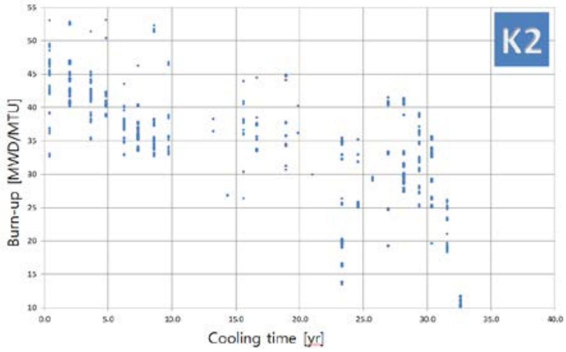

Fig. 3. The distribution of the fuel by the cooling period and burnup (WH type)

Table I: Fuel classification of WH type SNF

Type	Quantity [ea]	Cooling time Long/short [yr]	Burnup High/low [MWD/MTU]
SFA	14*	26.9 / 6.2	46,819 /19,294
KOFA	6*	24.6 / 23.3	35,505 /13,543
ACE7	13	8.6 / 2.0	52,829 /34,769

* Defective fuel was included in each 2ea of them.

Table II: Fuel classification of KSNP type SNF

Type	Quantity [ea]	Cooling time Long/short [yr]	Burnup High/low [MWD/MTU]
KSFA	12	20.9 / 12.2	54,085 /12,328
SFA	6	16.2 / 14.8	50,662 /32,150
GUAR DIAN	8	11.0 / 6.9	53,714 /39,759
PLUS7	6	6.9 / 5.6	55,561 /39642

2.4 Perform Demonstration Test

On Westinghouse type SNF, based on 100mm above the No.1 grid, SFA and KOFA were tested on one side and ACE7 was tested on two sides.

On KSNP type SNF, regardless of the fuel type, four-sided inspection was conducted based on the 100mm above the No.1 grid.

If abnormal detection signals are appeared, the characteristics of Ultrasonic detection signals are verified by changing the inspection position by 50mm in the upper or lower direction. When it was difficult to determine the defect through detection signal, test position, test face, gain and gate was changed to cross-check the same fuel.

2.5 Result of Demonstration Test

On Westinghouse type SNF, 20ea of SFA and KOFA were divided into long-term storage SNF form 26.9~15.6 year and short-term storage SNF from 9.7~6.2 year. Brunup rates are from a maximum of 46,819 MWD/MTU to a minimum of 19,294 MWD/MTU, and they are divided into high and low burnup rates at around 35,000 MWD/MTU. Low burnup SNF 12 ea showed clear detection signals of defect discrimination. Some of high burnup SNF 8ea showed low level detection signal. 13ea ACE7 have relatively short storage periods 8.6~2 year, but burnup rates are relatively high between 52,829 and 34,769 MWD/MTU. 5ea of low burnup rate fuel showed clear signal regardless of storage period. 3ea out of 8ea high burnup rate fuel showed clear detection signals, but 5ea of them, recently discharged fuel with a storage period of about 2year, showed low level detection signal and unclear detection signal.

Demonstration test for damaged 2ea SNF with relatively low burnup rates of 26,445 MWD/MTU and 25,256 MWD/MTU showed same result as the previous results, but damaged 2ea fuel with burnup rates of 36,245 MWD/MTU and 35,505 MWD/MTU showed different result for demonstration results vs. previous results. The defect discrimination WH type SNF shown in Fig. 4.

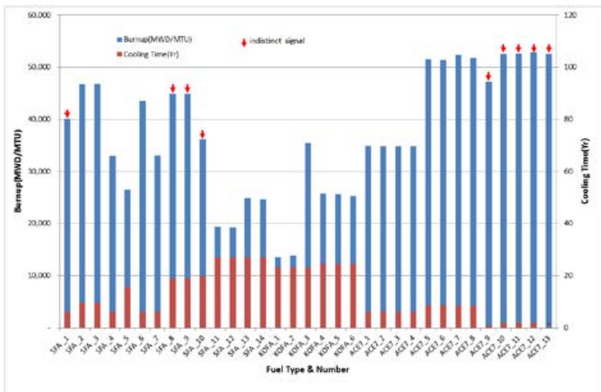

Fig. 4. WH type SNF detection signal

On KSNP type SNF, 18ea KSFA and SFA showed clear signals of defect discrimination regardless of burunup rates and storage period, and 8ea GUARDIAN and 6ea PLUS7 showed clear and good signals of defect discrimination regardless of burnup rates and storage period.

3. Conclusions

KSNP type SNF showed clear detection signal of defect discrimination, but WH type SNF showed a detection signal that it was not clear to determine the defects in the case of high burnup fuel. The results were reviewed to confirm the difference in fuel concentration at the inspection level. In the case of WH type SNF, inspection was carried out at 100mm above the No. 1 grid to avoid the bulging region of the control rod guide tube, but KSNP type SNF could be inspected at 50mm above the No. 1 grid. The inspection level for KSNP type SNF is a blanket area with a concentration of 2%

In the above demonstration test, detection signal from high burnup SNF tend to be unclear about the discrimination of defects. In addition, detection signals in low concentration area, blanket area showed clear defect discrimination.

REFERENCES

[1] Korea Radioactive Waste Management Corporation, Alternatives and Roadmap of Spent Fuel Management in South Korea, 2011.
[2] Jungmin Kang, The Search for interim Spent Nuclear Fuel Storage in South Korea, NAPSNet Special reports, August 31, 2015.